AEI

Electrical Distribution

THE NEWS MAGAZINE OF THE CABLE AND CONSTRUCTION (CABLES & LINES) DIVISIONS OF ASSOCIATED ELECTRICAL INDUSTRIES LTD

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EDITORIAL

A REVOLUTION in transport was presaged in the House of Lords recently by Lord Lucan when he envisaged a future in which not only liquids but solids could be transported by pipelines. He was speaking on the Esso Petroleum Company Bill which proposes two underground supply pipelines, each about seventy-five miles long, from their refinery at Fawley to west London and Avonmouth.

His vision of the transport by pipelines of wine across the Channel (or other liquids from Dublin) and the logical sequel of taps for such liquids in every household is one which, on contemplation, gathers an aura of mellow warmth round cluttered desks rather more in keeping with the festive season than all those electrical problems awaiting solution! On which titillating note we wish you a very Happy Christmas—an event which will not be far off by the time many of our readers receive this issue.

AEI

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OUR COVER PICTURE

A.E.I. cable at the Esso oil refinery at Fawley. An interesting account of the A.E.I. Construction (Cables and Lines) Division's work on this contract appears on page 57.

News in brief...

"Bill" Turner's Presentation

Mr F. V. Vaissiere (right) presents Bill Turner with his cheque for fifty years' service while Mr H. D. Parsons looks on.

BUSINESS FRIENDS OF Mr W. G. Turner, who has retired as manager of the A.E.I. Cable Division, Brighton Branch, will be pleased to know that he continues to serve the Brighton region in a consultative capacity.

At the Cable Division's head office at Hatton Garden, Mr Turner was presented with a cheque for £50—because the occasion of his "retirement" was also the occasion, to the day, of his completing fifty years' service.

The presentation was made by Mr F. V. Vaissiere, commercial manager, A.E.I. Cable Division. Earlier, Mr H. D. Parsons, divisional sales manager, had sketched Mr Turner's career since 1910 when he had been engaged as an office boy in the Stock Room at the London head office of W. T. Henley's Telegraph Works Co. Ltd.

After serving in the R.F.C. in the First World War, Mr Turner became senior order clerk. In 1939 he became manager of the Brighton Branch and a little later he opened the Canterbury cable store, becoming subsequently responsible for the south-eastern area.

Mr Turner was active in helping to organize the E.I.B.A. golf championship for many years and anyone who remembers the Henley Dramatic Society will recall his leading parts in many of their productions.

E.I.B.A.

FURTHER SUBSCRIPTIONS FOR the Electrical Industries Benevolent Association have been received since the initial list was published in our July issue. The following sums are gratefully acknowledged:

Messrs S. J. Beaney, £1 1s. 0d.; R. B. Hill, £1 0s. 0d.; H. J. Rand, 10s. 0d.; Anonymous, £1 0s. 0d.

Faraday Lecture 1960–61

"Transistors and all that"
by A.E.I. Director

MR L. J. DAVIES, C.B.E., M.A., B.SC., M.I.E.E., is to deliver his second Faraday Lecture—"Transistors and all that"—at eleven centres during 1960–61. Mr Davies gave the 1950–51 Faraday lecture on "Lamps and lighting—a record of industrial research". He is director in charge of research and education A.E.I. (Rugby) Ltd and a director of the A.E.I. Lamp & Lighting Company.

Recently, he has been responsible for the design of an extensive new A.E.I. research laboratory at Rugby, much of it planned specially for semiconductor work.

"Transistors and all that" is intended for non-technical audiences and describes the "how" and "why" of these semiconductors, their use, and manufacture.

Firstly, a quick glance is given to what transistors and semiconductor devices look like and what they can do and, very briefly, how they are made so that the audience gets on terms with the subject of the lecture. Secondly, since the devices are made from solids—no wires, no gas, no vacuum, no magnetic core, no moving parts—just a piece of solid, what is a solid and how is electricity conducted through it? How is it conducted through gases and through liquids? Why are the semiconductor solids different from others with special control of the minute traces of impurities on which their action depends? Thirdly, how can we make from them, or may one day be able to make from them, rectifiers, transistors, refrigerators and heat pumps, photoelectric power generators for satellites, and thermoelectric power generators for waste or other heat? Finally, how are we at present using transistors and other semiconductor devices and how are they likely to affect our future?

The lecture is illustrated by lantern slides and by short lengths of film including one on how to make a transistor. The experiments and demonstrations have been selected to illustrate many interesting points covered by the lecture.

Lecture Centres and Dates

Rugby (Temple Speech Room)	16 November 1960
Bristol (Colston Hall)	8 December 1960
Swansea (Brangwyn Hall)	13 December 1960
Manchester (Free Trade Hall)	24 January 1961
Leeds (Town Hall)	26 January 1961
Portsmouth (Guildhall)	14 February 1961
London (Central Hall, Westminster)	16 February 1961
Birmingham (Town Hall)	28 February 1961
Leicester (De Montfort Hall)	2 March 1961
Edinburgh (Usher Hall)	21 March 1961
Newcastle (City Hall)	23 March 1961

MAJOR PROGRAMME UNDER WAY....

How many people,
aware that the electrification of British Railways is
going forward, realize that the steam engine
needs servicing after only twelve hours of
running—and also needs a major inspection
every three to five weeks? An electric locomotive
can work for five continuous days before a
six-hour examination is made. A major
examination on an electric locomotive
is made after thirty days and includes
unit replacement of parts if required,
so it is soon back on the job.
Other, better known, advantages of electrification
are cleanliness, speed, and economy,
and the additional unseen advantage of using
the efficient product of "dirty" fuel instead of consuming
the high-grade coal burnt inefficiently
by the steam engine.
Two of the 25kV electrification projects recently
completed by British Railways
are described in this section.

GLASGOW SUBURBAN

PART OF THE forward-looking plan by British Railways Scottish Region to introduce 25kV overhead line electrification came to fruition on 7 November when "blue train" services north of the Clyde on the Glasgow suburban lines were inaugurated. The electrification of lines south of the river is scheduled for completion next year.

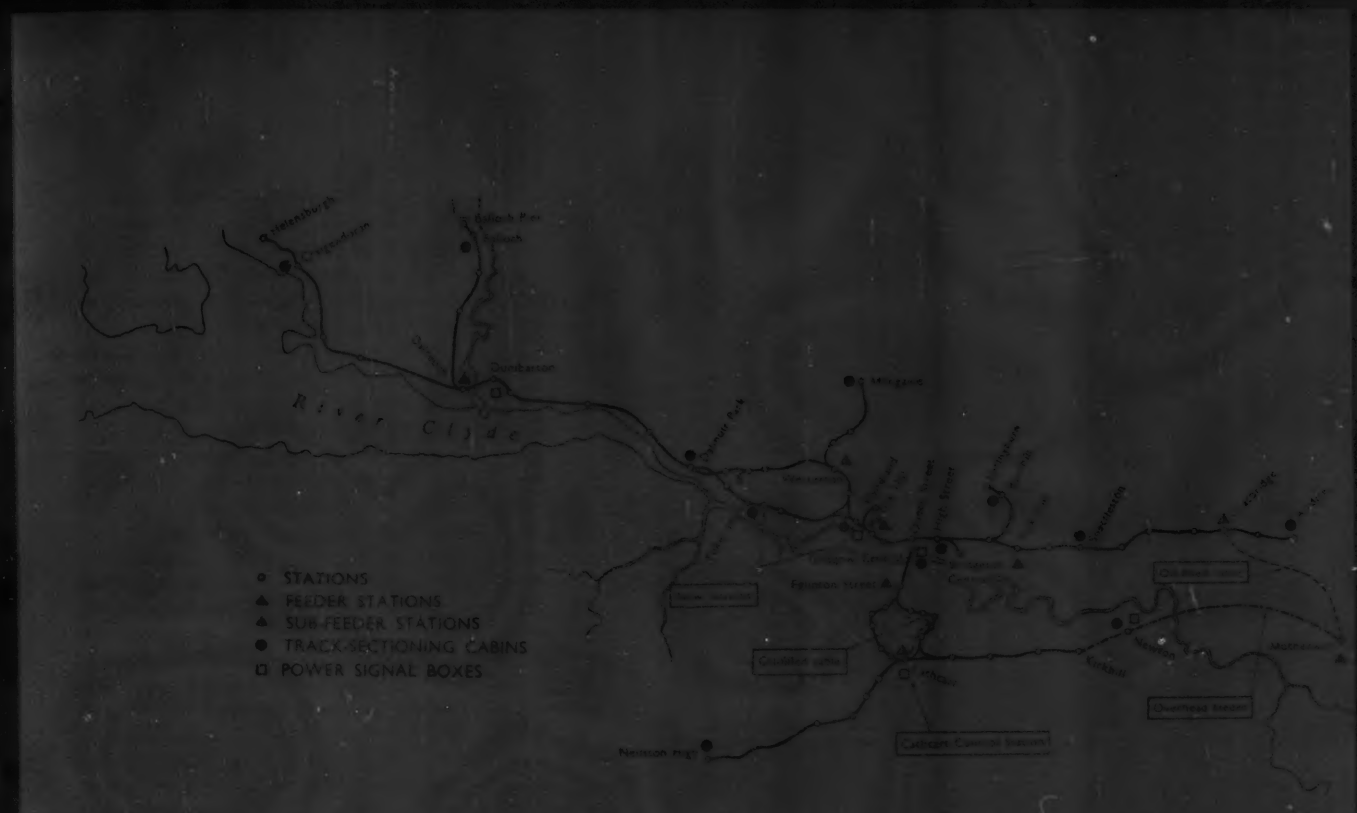
Several contracts concerned with the electrification plan have been entrusted to the Associated Electrical Industries organization during the past months. The Traction Division received an order for the electric traction, heating, and lighting equipment for ninety-one complete three-car sets of multiple-unit rolling stock—the "blue trains"—which combine passenger comfort with speed of service on the new lines. In these three-car trains the centre coach is the power vehicle. The mechanical parts are built by The Pressed Steel Co. Ltd at their Paisley Works.

The A.E.I. Construction (Cables and Lines) Division have carried out certain telecommunication, signalling, and power-cabling contracts, with which this article is primarily concerned. Their work is best viewed against a general pattern of the whole scheme, as depicted by the map and the following outline.

About seventy route miles of track are involved in the Glasgow and district electrification to date, in two phases—one north of the Clyde and one serving the south side of the river. The map shows the electrified lines from Helensburgh in the north-west through Queen Street in Glasgow's centre, to Airdrie in the east, with branches serving Balloch Pier, Milngavie, Bridgeton Central, and Springburn. The lines to the south are served from Glasgow Central; they run round the Cathcart Circle, south-west to Neilston High and south-east to Kirkhill.

Engineering Works

Many problems were inherent in the conception of the Glasgow plan. For example, the system is the first on which extensive underground sections have been met in 25kV electrification. On certain sections—including about three miles of tunnels—the working voltage is 6·25kV, as it is impracticable to provide the clearances necessary for 25kV working. In the centre of the city, also, civil engineering costs would have been excessive if 25kV clearances had been maintained and, as a consequence, the centre section has been designed to operate at the lower voltage.



Map of the Glasgow Suburban Electrification

The rolling stock, therefore, has been designed for this dual-voltage operation; the primary winding of the main transformer, located on the motor coach, is arranged in four sections, connected in series for a 25kV supply and in parallel for a 6·25kV supply. Changeover is effected automatically by an oil-immersed off-load changeover switch.

Even with the lower-voltage working, provision of the necessary clearances has involved track lowering throughout track sections north of the Clyde.

Other extensive civil engineering works necessary included station conversions; the raising or reconstruction of bridges at 148 sites and track lowering at twenty-eight other bridge sites; the realignment and recanting of curved track where necessary to deal with the higher speeds of the electrified trains; and major track layout remodelling at several places to increase the efficient running of the system.

Four feeder stations have been built—at Dalreoch, Parkhead, Eglinton Street, and Motherwell—and four sub-feeder stations are located at Westerton, Finnieston, Coatbridge, and Cathcart. The track is sectioned electrically at all these points and also at thirteen track-sectioning cabins sited at strategic positions.

The overhead system was installed by means of special works trains which carried mechanized equipment for the boring of foundation holes and the setting and concreting of masts into position. The overhead wires and fittings were installed by means of other works trains, and pantograph wagons tested clearances and the grading of overhead equipment.

Power Supplies

The power supplies for the north of Clyde area are normally derived from the South of Scotland Electricity Board at Dalreoch feeder station and Parkhead feeder station. The south of Clyde area is fed from the South of Scotland Electricity Board system at Eglinton Street feeder station and Motherwell feeder station.

In the event of failure of either of the two normal points on the north side, the remaining supply point feeds an area west of Parkhead feeder station and a supply from Motherwell feeder station is taken to Coatbridge sub-feeder station by means of a 25kV single-phase oil pressure cable and an associated 7-core pilot cable to feed the area east of Parkhead. Similarly, in the event of a failure of either of the two south side supply points at Eglinton Street or Motherwell, cable laid between

Eglinton Street and Cathcart sub-feeder station will be brought into use to enable supplies for electric traction throughout the area to be maintained.

The power-cable contract for the two cables just mentioned, valued at about £60 000, was awarded to Associated Electrical Industries. A.E.I. Construction Division engineers are responsible for the supply, installation, and jointing of cables, and the installation of the 10 000yd of concrete troughing at track level into which the cables are laid for most of the route.

Between Motherwell feeder station and Coatbridge sub-feeder station, 10 800yd single run of 0·3sq.in. aluminium conductor 25kV concentric 12mm central oil duct, lead alloy sheathed, reinforced oil-filled cable with anti-corrosive finish were laid alongside a non-electrified railway track between Motherwell and Coatbridge. At each end of the route the cable is terminated in oil-immersed sealing ends accommodated in the switchgear. Alongside the oil-filled cable is installed a 0·007in. 7-core paper-insulated, lead alloy sheathed, steel-tape armoured pilot cable with anti-corrosive finish. This cable includes feeder protection cores and also gives remote indication, on the control diagram at Cathcart Control Station, of the operation of any of the four low-pressure alarm switches which are installed on this part of the oil-filled cable system.

A similar oil-filled cable and associated pilot cable will also be installed, mainly in concrete troughing, between the Eglinton Street feeder station and Cathcart sub-feeder station along the east side of the Cathcart circle—a distance of 4 200yd. Two low-oil-pressure alarms are fitted to the system.

As is usual on railway cabling jobs, the distribution of materials and laying of cables were carried out at night from works trains, except for short sections where hand pulling of cables was necessary at track crossings. In this way certain work, such as the installation of troughing, goes on during the day and full advantage is taken of traffic conditions on the permanent way.

Cathcart Control Station just mentioned is a new building from which the electrical control of the entire area is supervised. Feeder stations, sub-feeder stations, and track-sectioning cabins on the system are unattended, and controlled from Cathcart. A mimic diagram in the control room shows the positions of oil-circuit breakers, which control the incoming and outgoing supplies at feeder stations, sub-feeder stations, and track-sectioning cabins. It also shows certain motorized overhead switches.

(Above)
25kV oil-filled cable being fed into under-track crossing at Whifflet North Junction.

◀ Cables in troughing and under-track crossings at Whifflet North Junction and through Whifflet (lower) station.

Signalling

The old semaphore signals are inadequate for the improved services resulting from electrification and, along the electrified lines, must be completely replaced by the modern colour light system.

As colour light signalling is so essential to full performance at the fast speeds which electrification makes possible, the importance of power supplies for the signalling needs no emphasis. The main 415V supply from the South of Scotland Electricity Board is used to supply signalling power through 415/650V single-phase transformers at switching stations and, in addition, 25kV/650V or 6·25kV/650V voltage-regulated transformers are installed at stations or cabins for standby supplies should the mains supply fail.

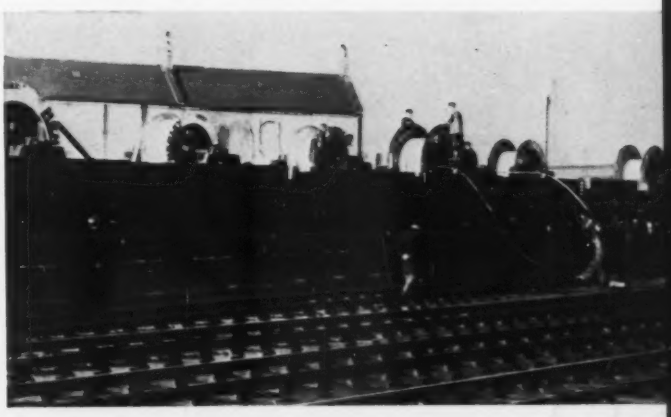
Colour light signalling is, or will be, provided on all electrified lines north and south of the Clyde. During the past twenty-two months A.E.I. Construction Division engineers have laid, jointed, and connected to signalling equipment, 160 miles of multicore signalling and power signalling cables for this work, under a contract placed with A.E.I.–G.R.S. Limited by the British Transport Commission.

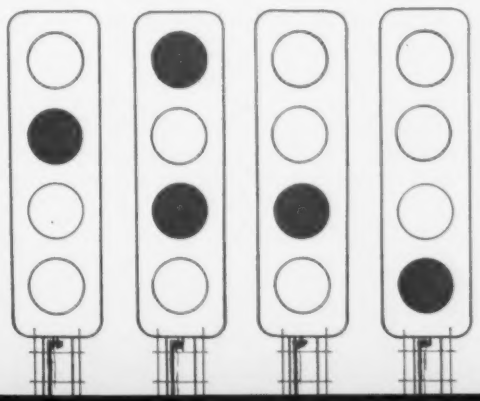
This Construction Division work, having a total value of well over a £¼ million, has been concerned with the western part of the north of the Clyde phase. It covers signalling requirements for the whole of the track from Partick Hill, in the centre of Glasgow, to Helensburgh, including the spurs to Ballock Pier and Milngavie, and also the spur to Hyndland where the new rolling-stock maintenance sheds have been constructed.

Here, again, the cables were largely laid into trackside concrete troughing at night from train-mounted drums—except where obstructions or track congestion made laying by hand essential. The multicore signalling cables are of 1/·044in. conductor size, laid up in various pair formations, VIR/PCP insulated and sheathed with PCP; the small power type cables are VIR insulated.

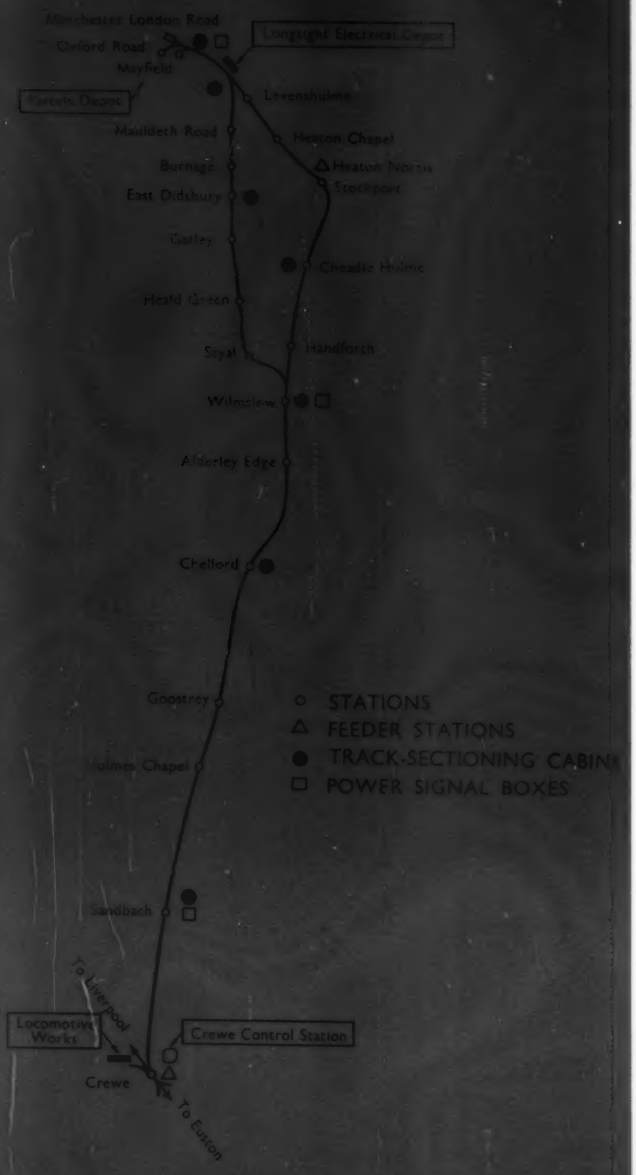
To dismiss these contracts by a brief reference, against the larger background of the whole Glasgow suburban electrification scheme, gives little indication of the amount of organization and construction work behind them. From the ordering of the cables, their manufacture at one of the A.E.I. cable-making factories, their dispatch and installation, to their jointing and final testing, many men (and women) have concentrated experience and skill on their several tasks to ensure that these vital channels of power and speech will do the job expected of them.

▲ **Cables being pulled from cable train into troughing near Whifflet South. (Note tight clearance between wagons and cutting slope).**





Manchester–Crewe



The forty-mile Manchester–Crewe 25kV a.c. single-phase electrification, London Midland Region, on which the first train service was inaugurated in September, is intended as the first part of an overall plan to electrify the major railway lines between London, Manchester, and Liverpool.

The section takes power supplies from the Central Electricity Generating Board 132kV grid *via* a 25kV concentric cable to railway-owned feeder stations sited at Heaton Norris and Crewe. If the supply from one feeder station should fail it is possible to extend the feeding limits of the other feeder station by suitable switching operations.

A new control room at Crewe supervises the area (and will control future electrification to Liverpool and some to the south of Crewe) as, in common with the general London–Midland electrification scheme, all feeder stations and track-sectioning cabins are remotely controlled. The mimic diagram in the control room displays oil-circuit breakers and overhead line motorized switching positions; alarm indicators and meter readings are also available in the control room.

Colour light signalling has been installed in the interests of speedier traffic on all the electrified lines as the local trains are capable of 75m.p.h. and the main-line locomotives can haul at 100m.p.h. Three new power signal boxes—at Sandbach, Wilmslow, and Manchester London Road—replace twenty-seven old-type signal boxes in the Manchester–Crewe area. The new box at Manchester London Road is the largest, coping with 500 signalled routes, and controlling an area formerly covered by thirteen mechanical and obsolete electrical signal boxes: to Gatley on the Styal line, Heaton Chapel on the Stockport line, and Ashburys on the Sheffield line, including the connections serving the Longsight depots.

One of the four-car multiple-unit sets, for which A.E.I. supplied the electrical equipment, running on the Manchester–Crewe local services.

A large track structure on which A.E.I. 25kV solid type cables have been installed and terminated.

Associated Electrical Industries have played an important part in the scheme, providing main-line locomotives, power cabling, and electrical equipment for the new four-car multiple-unit local trains.

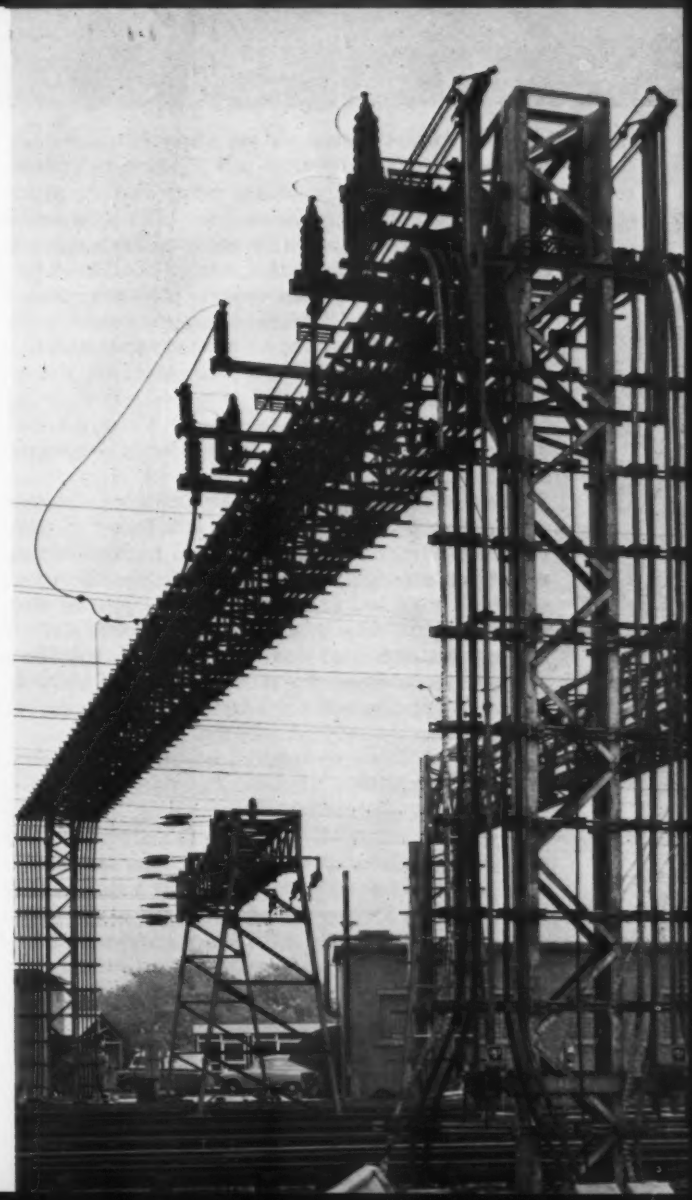
All the electric traction cable installation was the responsibility of the A.E.I. Construction (Cables and Lines) Division. The work involved the supply and laying of 26 000yd of 25kV 0·20sq.in. single-core paper-insulated lead alloy sheathed solid type cables with anti-corrosion finish in trackside buried route or surface concrete troughing, their installation on overhead track structures, more than 100 terminations in sealing ends on overhead structures and a similar number of terminations at the switchgear in feeder stations and track-sectioning cabins, and the supply and jointing of the necessary straight-through joints.

A special platform was designed to enable the jointers to make off 25kV sealing ends on the overhead structures while normal rail traffic was running.

Where a break in the overhead spans is required for switching purposes, or at the end of tension lengths in the overhead line equipment, overlap spans are required. Generally, neutral sections are installed on the system where there is a change of voltage and at locations connected with feeder station positions and emergency feeding conditions.

Multicore and low-tension cables, associated with motorized switches for remote isolation and the control of neutral sections, were also part of the work carried out by A.E.I. engineers, as were various medium-voltage cable installations at track-sectioning cabins and feeder stations.

In order to limit leakage of traction return current *via* the earth, a booster transformer rail return system is used on the Manchester–Crewe sections (other sections of the



Locomotive E3001 passing Jodrell Bank radio telescope. This locomotive is one of twenty-five designed at A.E.I.'s Rugby Works.

London–Midland system will use a booster transformer and return conductor system where necessary). Approximately 50 000yd of 0·15sq.in. single-core 250V v.r. cables were installed under the contract for track return purposes, booster transformer to track connections, and return conductors. This work, for much of which A.E.I. cable was used, involved the making of 1200 terminations.

Construction Division engineers also completed the depot and yard lighting schemes at Crewe and installed a number of control cables at the Longsight and Crewe depots.

All this cabling work, progressing along with the three-year preparation for the electrification, was worth more than £150 000.

It must be remembered that the thirty-one-mile route length between Manchester and Crewe requires 117 miles of track to cover it. The civil engineering task was immense—eighty-two bridges of the ninety-two along the route had to be heightened to provide electrical clearance, tunnels had to be opened out, stations were reconstructed, and track layouts remodelled. There was even a subsidence area to cope with near Sandbach, where the rate of subsidence is expected to continue year by year.

A.E.I. 3 300h.p. locomotives are used on the Manchester–Crewe tracks. Eventually, thirty-five A.E.I. manufactured locomotives will be among the first 100 used on the London–Midland electrification for hauling long-distance passenger and freight trains. These locomotives have voltage selection equipment and automatic changeover for 25kV/6·25kV line voltages as, when the whole scheme is complete, the inner London and Birmingham areas will be energized at 6·25kV.

However, local services on the Manchester–Crewe–Liverpool section will eventually be served by forty-five four-car multiple-unit sets which comprise battery driving trailer, motor coach, trailer, and driving trailer cars. Their top speed is 75m.p.h. The units can be coupled to form four-car, eight-car, or twelve-car trains. These are British Railways built, with electrical equipment supplied by A.E.I. The motor coach mounts pantograph and air-blast circuit-breaker on the roof and carries the main transformers (25kV or 6·25kV supply) and germanium rectifiers on the underframe.

A feature of the safer travelling which the new signalling should herald is the automatic warning system (A.W.S.) designed to work in conjunction with it. A pair of inductors at the approach to each running signal reacts on receiver units in the locomotives or multiple-unit trains. If the signal is at 'stop' or 'caution' a warning horn is sounded in the cabin and if the driver ignores this audible signal the brakes are automatically applied. If the signal is at 'clear' a bell is sounded in the cab and the driver has confirmation that he may proceed. The A.W.S. will make for increased safety in times of fog.

The new, efficient service on these lines, which is the result of three years' hard work (and many headaches!) on the part of British Railways, is an example of what can be expected as 25kV electrification is extended. The traveller between Manchester and Crewe alights after a comfortable forty-minute journey in a smooth-running train. He can anticipate the day when it is possible to travel from Euston to Liverpool, experiencing just such a comfortable journey made as safe as it is humanly possible to make it, in surroundings far cleaner than was possible in the days of dirt and steam.

Earthing in Power Systems

by A. SALZMANN, Dipl.Ing., A.M.I.E.E.

PART 2

This is the second part of an article reviewing neutral earthing in high-voltage transmission. Part 1, *which appeared in the September issue of* ELECTRICAL DISTRIBUTION, *treated of theoretical considerations, fault current and fault voltage calculation, and solid earthing.*

Resistance earthing

Here a resistance is intentionally inserted between neutral and earth with the object of decreasing the fault current but at the expense of increased steady-state line-to-earth voltages of the healthy phases. In fact, resistance earthing should be considered as a non-effectively earthed system because of increased R_N (resistance earthing) so that the ratio Z_0/Z_1 becomes positive and larger than 1·0.

However, the earthing resistance can be adjusted so that the lagging component of the fault current I_{Fl} is equal to the resultant capacitance current I_c of the system, the latter being cancelled in the fault path, hence no arcing ground fault can occur and no build-up of high voltages is possible. This is illustrated in the vector diagram, Fig. 5, assuming an earth-fault on the red phase. If the neutral is insulated, the resultant capacitance current I_c will be present, but when earthing the neutral point, fault current I_F will flow in addition to current I_c. Combining both currents and adjusting the neutral earthing resistance so that I_{Fl} becomes equal or greater than the capacitance current I_c, no overvoltage conditions are likely to be present.

Summarizing: the earthing resistance is selected with the objects of

(a) reducing the fault current to a value permitting the protective gear to clear faults discriminately.

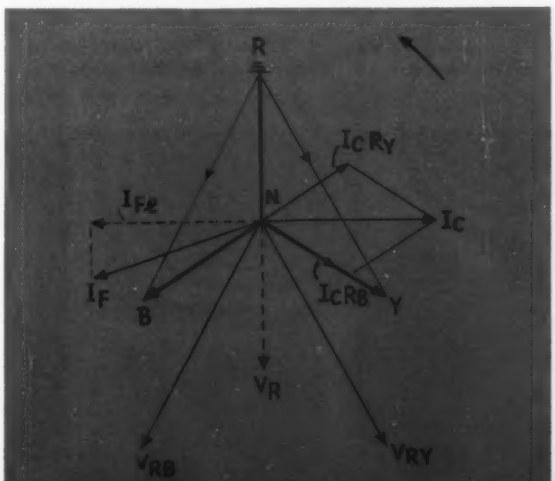


Fig. 5. System vector voltages and currents subsequent to an earth fault on phase R on a system with adjustable neutral resistance.

(b) limiting the overvoltage to a value having no harmful effect on system insulation.

Artificial neutral earthing

Any system supplied *via* a star/delta connected transformer will require an artificial, earthed neutral point. This can be accomplished by utilizing an interconnected star earthing transformer, having a very low impedance to the zero phase-sequence current (see Fig. 6). This unit is designed to carry the maximum fault current for about thirty to sixty seconds. Generally, the transformer is connected to earth *via* neutral resistance because of its very low zero phase sequence impedance, particularly when it is required to limit the fault current. However, the ohmic value of the earthing resistance should be related to the earth-fault setting of the protective gear. The setting should be not higher than 50% of the minimum fault current.

Reactance earthing

Reactance earthing should be considered as a non-effectively earthed system because of the increase of X_N—hence $k=Z_0/Z_1$ becomes positive and larger than 1·0. A low value of reactance is generally used for extra-high-voltage systems with the object of reducing steady-state overvoltages between healthy phases and earth.

High-reactance earthing is applied for earthing the neutral point of alternators through a single-phase potential transformer. In fact, a system neutral connected to earth *via* a single-phase voltage transformer is to be considered as an insulated neutral system. However, overvoltages due to arcing ground phenomena are less severe because of the negligible capacitance (short length of cable between generator and transformer) and the fact that the zero sequence networks on either side of the delta/star connected transformer are isolated from one another.

The most popular application of reactance earthing is the use of a reactor in resonance with the capacitance of the system (resonant neutral earthing or arc-suppression coil earthing). The arc-suppression coil (A.S.C.) is an iron-core reactor connected between the neutral of the system and earth, the winding being provided with tappings for adjustment of the coil inductance to suit the length of the network. The coil is designed to pass reactive current equal to the total capacitive current of the transmission system when one phase is earthed. Resonant earthing makes arcing earth-faults self-extinguishing and in the case of sustained earth-faults the coil reduces the fault current at the point of fault to a small value (residual current).

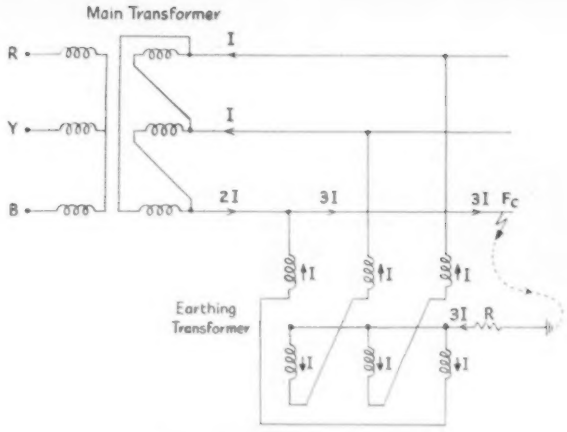


Fig. 6. Earth-fault conditions on a system earthed artificially via an earthing transformer.

Thus the main advantage of A.S.C. earthing is the reduction of the fault current under perfect tuning conditions to about 10% and shifting nearly in phase with the system voltage. At the instant of "current zero" the voltage across the gap will also be zero; it will rise at a slow rate (of the 50c/s wave) and possibly will not restrike, particularly if the residual current is small enough to reduce ionization of the air to a low value. However, the slow reappearance of the system voltage (about ten to twenty times as slowly as in solidly earthed networks after the extinction of the arc) does not always materialize in E.H.T. systems, owing to large corona loss, and this is one of the main reasons why A.S.C. earthing is not used in such systems.[4]

Attention should be given to the length of time of coil operation in the event of line-to-earth faults. Alteration of the earth-plate contact resistance may lead to dangerous voltage drop in the ground and possible danger to human life and animals.

So long as the neutral is accessible no difficulties will arise in using A.S.C.s but where no neutral point is available the coil can be connected to the system *via* a star interconnected earthing transformer.

Alternatively, an arc-suppression transformer (A.S.T.), known on the Continent as a "Bauch Transformer"[5] and shown in Fig. 7, can be employed and connected to any suitable point of the network. This transformer consists of a star-connected primary with solidly earthed neutral and a delta-connected secondary having a tapped reactor inserted in the winding. The latter is so adjusted that in the event of a line-to-earth fault the reactive current I_L is equal and in phase opposition to the earth-fault capacitive current I_{c1}, assuming negligible system losses. The A.S.T. reduces the fault current at the point of fault to a small value thus preventing an arc restriking in a manner similar to that of an A.S.C.

Conclusion

Operation of large transmission systems with insulated neutral is out of date in modern practice. For power systems operating during periods of disturbances with insulated neutral, adequate precautions have to be taken to prevent generation of transient overvoltages.

For systems operating at voltages in excess of 110kV, solid earthing is predominantly used. In these networks transient faults are cleared by high-speed auto-reclosers.

For h-v systems operating at or below 110kV, limitation of the earth-fault current is secured by low reactance neutral earthing, but not at the expense of an increase of the system insulation level. In the case of resonant neutral earthing the fault current is reduced at the location of fault theoretically to zero but at the expense of higher insulation level than in effectively earthed systems.

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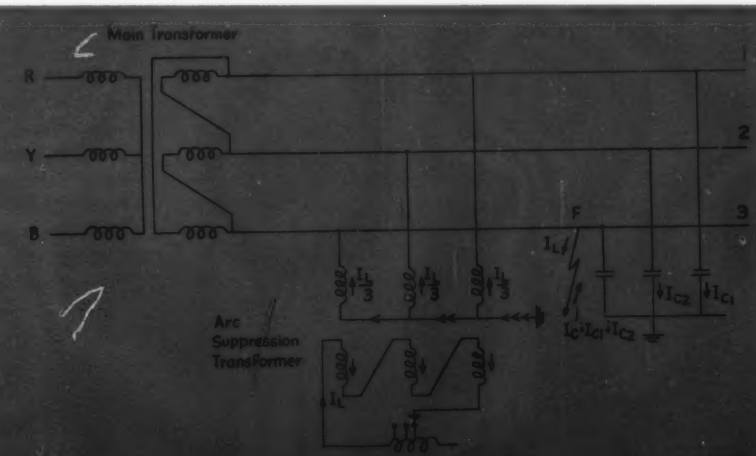


Fig. 7. Diagram of a 3-phase power transmission system protected by an arc-suppression transformer.

Appendix No. 1. Symmetrical Components: Basic Equations

According to the late Dr Fortescue, any unbalanced system of currents or voltages can be resolved into three separate systems:

1. A positive balanced system with phases 120° apart rotating as the original system.
2. A negative balanced system with phases 120° apart but rotating in reverse direction to the original system.
3. A zero sequence system comprising three equal and co-phasal components of the same magnitude.

The object of the application of symmetrical components for network analysis is, therefore, to adopt the same method as for balanced fault currents, i.e. using one phase only. Thus for unbalanced faults, such as single line-to-earth faults, calculations can be simplified by reducing the network to a single equivalent circuit containing positive, negative, and zero sequence impedances, as illustrated in Fig. 1, for a fault at the location F.

From the conditions existing in the network at the occurrence of the fault we can determine currents and voltages for any type of fault by aid of the equations given below.

I. Sequence currents expressed in terms of line currents.

$$I_{r0}=1/3(I_r+I_y+I_b) \quad \ldots\ldots(1)$$

$$I_{r1}=1/3(I_r+aI_y+a^2I_b) \quad \ldots\ldots(2)$$

$$I_{r2}=1/3(I_r+a^2I_y+aI_b) \quad \ldots\ldots(3)$$

where a=vector operator$=-0{\cdot}5+\mathrm{j}0{\cdot}866$, $a^2=-0{\cdot}5-\mathrm{j}0{\cdot}866$, and **suffixes** 0, 1, and 2 denote zero, positive, and negative phase-sequence components.

II. Line currents expressed in terms of phase-sequence currents.

$$I_r=I_{r0}+I_{r1}+I_{r2} \quad \ldots\ldots(4)$$

$$I_y=I_{r0}+a^2I_{r1}+aI_{r2} \quad \ldots\ldots(5)$$

$$I_b=I_{r0}+aI_{r1}+a^2I_{r2} \quad \ldots\ldots(6)$$

III. Sequence voltages expressed in terms of phase voltages.

$$V_{r0}=1/3(V_r+V_y+V_b) \quad \ldots\ldots(7)$$

$$V_{r1}=1/3(V_r+aV_y+a^2V_b) \quad \ldots\ldots(8)$$

$$V_{r2}=1/3(V_r+a^2V_y+aV_b) \quad \ldots\ldots(9)$$

IV. Phase voltages expressed in terms of phase-sequence voltages.

$$V_r=V_{r0}+V_{r1}+V_{r2} \quad \ldots\ldots(10)$$

$$V_y=V_{r0}+a^2V_{r1}+aV_{r2} \quad \ldots\ldots(11)$$

$$V_b=V_{r0}+aV_{r1}+a^2V_{r2} \quad \ldots\ldots(12)$$

V. Phase sequence voltages expressed in terms of sequence currents and impedances.

$$V_{r0}=0-I_{r0}Z_0 \quad \ldots\ldots(13)$$

$$V_{r1}=E-I_{r1}Z_1 \quad \ldots\ldots(14)$$

$$V_{r2}=0-I_{r2}Z_2 \quad \ldots\ldots(15)$$

where E=generated voltage and Z_0, Z_1, Z_2 are resultant sequence impedances viewed from the fault location. It should be pointed out that the above equations are applicable for any type of fault. For example, for a "red" line-to-earth fault, no modification of the above equation will be required. However, if the yellow phase is involved and the phase marking is R-Y-B the yellow phase becomes, for the purpose of calculations, phase R, the blue phase becomes phase Y, and the red phase is phase B. Similarly, if the blue phase flashes over to earth the latter becomes, in the above equation, phase R, the yellow phase becomes phase B, and the red phase is phase Y. In a similar manner, we can calculate fault currents and voltages for various type of faults with different phases involved, by one of the given equations.

Example: Derive from the above equation for a single line-to-earth fault (red phase involved) for fault currents and line-to-earth voltages.

Conditions at the fault are

$$I_y=I_b=0 \quad \ldots\ldots(16)$$

$$V_r=0 \quad \ldots\ldots(17)$$

assuming $R_F=0$. Substituting for $I_y=I_b=0$ and $V_r=0$, we obtain, from equations 1, 2, and 3,

$$I_{r0}=I_{r1}=I_{r2}=1/3I_r \quad \ldots\ldots(18)$$

From equation 10, $V_{r1}=-(V_{r0}+V_{r2})$ and equations 13, 14, and 15 we give fault current

$$I_r=(3\times E)/(Z_1+Z_2+Z_0) \quad \ldots\ldots(19)$$

where E is expressed in volts and Z_0, Z_1, Z_2 in ohms.

Similarly, line-to-earth voltages at the location of fault are obtained by combining equations 10, 11, 12, 13, 15, and 19 thus:

$$V_y=-\tfrac{1}{2}\sqrt{3}E\frac{\sqrt{3}Z_0+\mathrm{j}(Z_0+2Z_1)}{2Z_1+Z_0} \quad \ldots\ldots(20)$$

$$V_b=-\tfrac{1}{2}\sqrt{3}E\frac{\sqrt{3}Z_0-\mathrm{j}(Z_0+2Z_1)}{2Z_1+Z_0} \quad \ldots\ldots(21)$$

It should be noted that for a 3-phase fault, equation 19 becomes

$$I_{3\phi}=E/Z_1 \quad \ldots\ldots(19a)$$

Impedance Z_1 expressed in terms of any arbitrarily selected base current I_B and per cent impedance ohms ($Z_1\%$) gives us $Z_1\text{ohms}=(EZ_1\%)/(I_B100)$. Equation 19a can be written, therefore, $I_{3\phi}=(100I_B)/(Z_1\%)$. Alternatively expressed in per unit notation we can write $I_{3\phi}=[(100/100)\times I_B]/[(1/100)Z_1\%]=I_B/Z_v$ p.u. where $Z_v=0{\cdot}01Z_1\%$ (see Appendix 2). In a similar manner we can rewrite equation 19 with Z_0, Z_1, Z_2 expressed as percentages: $I_r(\text{amps})=(300\times I_B)/(Z_0\%+Z_1\%+Z_2\%)$, hence, expressed in per unit, $I_r=(I_B)/(\cdot01Z_0\%+\cdot01Z_1\%+\cdot01Z_2\%)$ p.u., where $I_B=1{\cdot}0$ p.u.

Appendix No. 2. Per Unit Method

When symmetrical components are used for solving network problems, particularly where applied to sy... ...ms

having several voltage levels, such as transformer feeders with step-up and step-down units having different name-plate ratings and operating on different taps, per unit notation should be considered as a useful tool in the hands of engineers, and should be given preference to other methods of calculations.

Per unit values are the ratios of actual currents, voltages, kilowatts, and impedances to their corresponding base values.

In the form of an equation, we can write

$$\text{p.u.} = \frac{\text{Actual Value}}{\text{Base Value}} \quad \ldots\ldots\ldots\ldots (1)$$

Clearly only two arbitrary base values, usually MVA and kV, are required, while current and impedance are obtained by calculations. As a general rule the selected base should yield unity per unit values, which means power and voltage bases being equal to the corresponding rated values of selected circuit element.

Formulae: Considering a circuit element with an impedance voltage

$$Z\% = [IZ(\text{ohms})100]/(V_{ph}) \quad \ldots\ldots\ldots (2)$$

where I = rated current = base current, Z = line-to-neutral impedance, V_{ph} = line-to-neutral voltage selected as base voltage.

By dividing equation 2 by 100 and substituting for $[Z\%/100] = Z_u$, (per unit value), we get

$$Z_u = \frac{Z(\text{ohms})}{(V_{ph})/(I)} = \frac{Z(\text{ohms})}{(\text{Base Voltage})/(\text{Base Current})}$$

$$= \frac{Z(\text{Actual Value})}{Z_B(\text{Base Value})} \quad \ldots\ldots\ldots\ldots (3)$$

This equation satisfies the definition given in equation 1. Expressed in terms of impedance, base MVA and base voltage, and substituting for $I = [(\text{MVA})10^3]/[\sqrt{3}V]$ and $V_{ph} = (V10^3)/\sqrt{3}$ we obtain

$$Z_u = [Z(\text{ohms})\text{MVA}]/[V^2(\text{kV})] \text{ p.u.} \quad \ldots\ldots (4)$$

Generally, rated values such as MVA and kV differ from those selected arbitrarily for base values, and conversion of per unit values from one base to another is necessary. For example, if the name plate or rated values of power output (MVA) and voltage (V) of a generator are selected as base values, the per unit impedance is obtained from equation 4. For bases, say, MVA_1 and V_1 the per unit impedance is, according to equation 4,

$$Z_{u1} = (Z \times \text{MVA}_1)/(V^2) \quad \ldots\ldots\ldots (5)$$

or Z_{u1} expressed in terms Z_u is obtained from equations 4 and 5 as

$$Z_{u1} = (Z_u\text{MVA}_1)/(\text{MVA}) \quad \ldots\ldots\ldots (6)$$

Per unit impedance referred to bases MVA and V_1 is

$$Z_{u2} = (Z \times \text{MVA})/(V_1^2) \quad \ldots\ldots\ldots\ldots (7)$$

or by combining equations 4 and 7:

$$Z_{u2} = (Z_u V^2)/(V_1^2) \quad \ldots\ldots\ldots\ldots (8)$$

In a similar manner, per unit value at bases MVA_1 and V_1 is

$$Z_{u3} = (Z \times \text{MVA}_1)/(V_1^2) \quad \ldots\ldots\ldots\ldots (9)$$

or by combining equations 4 and 9 we obtain

$$Z_{u3} = Z_u \frac{\text{MVA}_1 V^2}{\text{MVA} V_1^2} \quad \ldots\ldots\ldots\ldots (10)$$

New British Standards

B.S. 607:1960—Concrete Poles for Electrical Transmission and Traction Systems

This specification has been revised and its scope extended to cover requirements for prestressed poles and prestressed poles that may be exposed to impact.

The standard provides design requirements and test procedures for reinforced concrete and prestressed concrete poles suitable for supporting electrical transmission and traction lines, including supports for telegraph and telephone lines. (It does not apply to lighting columns—these are dealt with in B.S. 1308, *Concrete street lighting columns*.)

There are six classes of pole based on minimum ultimate transverse loading: and the specification embraces materials, methods of manufacture, earthing, standard lengths and loads, type tests, and proof tests.

Recommendations for the provision of pole holes are given, and particulars of pole markings are also included. *Price* 4*s*. 6*d*.

B.S. 936:1960—Oil Circuit-breakers for Medium Voltage A.C. Systems

This revised standard is now generally in line with other specifications for switchgear such as B.S. 116 and B.S. 3078.

The standard applies to three-pole circuit-breakers suitable for use on 3-phase industrial and supply distribution systems, having voltages up to 660V and breaking currents not exceeding 43·3kA. The circuit-breakers are intended for use in those parts of a system where marked asymmetry in short-circuit currents cannot occur and where short-circuit operating duty requirements and restriking voltage conditions are less severe than those envisaged for circuit-breakers complying with B.S. 116—the standard for oil circuit-breakers for alternating-current systems. *Price* 15*s*. 0*d*.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W.1 (postage extra to non-subscribers).

Special Cables for Space "Ear"

THE SECOND LARGEST steerable radio telescope in the world will be operating in Australia next year.

Britain's Jodrell Bank radio telescope is familiar to everyone with an interest in science and engineering. It is located at a latitude of 53°N., which means that part of the southern hemisphere is cut off from its field of reception.

The Radio Physics Laboratory of the Commonwealth Scientific and Industrial Research Organization has therefore planned the construction of another radio telescope, to be built in Australia near the town of Parkes, 200 miles west of Sydney, at a latitude of 33°S. It will be slightly smaller than the Jodrell Bank structure but will incorporate more precise control machinery.

A.E.I. are supplying all the telescope's electrical apparatus including cabling, lighting, and communications equipment. The A.E.I. Electronic Apparatus Division's servo group is designing and manufacturing the servo control system and is responsible for the accurate positioning of the dish.

The paraboloidal reflecting dish of the new telescope is 210ft diameter. It is carried by a turret which revolves on top of a concrete tower. Overall height of the structure is about 190ft and the weight of the moving parts some 850 tons, of which 650 tons is on the altitude bearings.

The chief reason for choosing the Parkes area is its low level of electrical noise—which means that very weak signals from distant stars may be received without superimposed interference. The necessity for trouble-free reception of signals from space, by the extremely sensitive telescope receivers, also dominated the design considerations for all the telescope's electrical apparatus, so that radio noise is prevented as far as possible.

For this reason, when the question arose of the transference of power supplies, communications, and signals from the base tower to the rotating turret, the use of slip-rings was not considered suitable owing to the risk of generating electrical noise. It was decided to use flexible twisting cables and to overcome the further problem of accommodating the twist imposed by the horizontal rotation of the dish through $\pm 225°$ by designing a special cable-twisting system.

The solution to relieving the cables of excessive strain was to provide "floating suspension". The cables coming up from the tower are clamped to the walls of a stationary inner tower which protrudes through the centre of the turret. From these clamps the cables fall freely to a floating ring 10ft below, are clamped to this

ring, and ascend freely again to be clamped to another ring which is driven at half the speed of the turret. The cables then fall to another floating ring to which they are clamped and are finally brought up again to be clamped to the walls of the turret.

This method ensures even distribution of load on the cable during twisting. Junction boxes terminate the cables on the walls of the turret and on the inner tower to allow easy replacement of cables when necessary. The twister carries twenty-four multicore cables for control purposes, with facilities for twelve special r.f. cables for use with radio equipment.

Although the twister minimizes load on the cables, the latter were specially designed to withstand mechanical stresses. Manufactured at A.E.I.'s Lydbrook cable factory, their basic construction is 40/.0076in. tinned copper conductors, butyl rubber insulated, tinned copper wire braided, thirty-nine cores laid up, taped, braided with tinned copper, and sheathed with a heavy duty p.c.p. Each core is specially taped and the whole laid-up assembly is internally "lubricated" to reduce the strain on the cores during the twisting and bending cycles.

Other cables manufactured for the telescope, but not subject to the twisting stresses described, are also butyl-rubber insulated and p.c.p. sheathed overall. All the cables mentioned are braided with tinned copper and special glands are used for terminating the braids.

A further feature in the design of these cables is the specified condition that they must operate in direct sunlight and at an ambient temperature of 140°F.

Precautions taken to prevent electrical interference of the all-important signals received by the telescope include the special housing of relays and contactors in sealed compartments; a sealed metal room in which the metadyne/generator set is housed; screening cams fitted to all servo motors, and the cables between servo motors run in conduit whose joints are sealed against electrical leakage.

When the Parkes radio telescope is in operation its reflecting dish will rotate about an axis parallel with the earth's polar axis, at the desired angles of declination, at such a speed as to remain steadily pointed at its objective in spite of the earth's rotation. It will be capable of automatic scanning of different sectors of the sky and will also, for certain purposes, be manually controlled. Its operational range will be 0–60° from zenith in the altitude motion and ±225° about 70°E. in the azimuth motion.

It will have safety devices which come into action at the limits of each motion and others designed to prevent damage in emergencies. At wind speeds in excess of 20m.p.h. the dish will be stowed in the zenith position.

The consulting engineers for the project are Freeman, Fox and Partners of London. The paraboloidal dish and the rotating turret structure are being manufactured by the main contractors, Maschinengabrik Augsburg-Nurnberg AG (MAN), West Germany, and the astronomical equipment by Askania Werke of Berlin.

$3m. E.H.V. Cable Project

THE CORNELL extra-high-voltage cable testing station which was opened in September has been specially built to carry out field tests on underground cable systems designed for 345kV and 500MVA. The station is sited at Cornell Universiry, New York State.

Four different screened-conductor cable types are to be subjected to analysis at this station: a low-pressure (12psig nominal pressure) paper-insulated, screened, lead sheathed stainless steel tape reinforced cable, sheathed overall with polyethylene; a high-pressure paper-insulated, screened, aluminium sheathed self-contained oil-filled cable with a high-density, high-molecular weight polythene oversheath—oil maintained at 200psig nominal pressure; a high-pressure oil pipe-type cable paper-insulated, screened, polyester film/fabric insulated and bronze wire armoured—two such cables installed in a 10¾in. o.d. steel pipe filled with oil maintained at 200psig; and a high-pressure oil pipe-type cable with concentric enamelled conductors, paper-insulated, screened and moisture sealed, with polyethylene skid wire—two such cables installed in a 10¾in. o.d. steel pipe filled with oil at 200psig.

In a three-year research programme, cable voltages will be raised in steps during the first two years from 345kV to 415kV at service operating temperatures and in the third year voltages will be raised to 500kV at increased temperatures.

For Architects

AN EIGHTEEN-PAGE illustrated booklet has been produced by the Electrical Development Association for architects. Its title: **Notes on the Construction and Finish of Floors that are to be Electrically Warmed.**

Floor warming is considered mainly from the structural aspect. Floor construction, floor finishes, sound and thermal insulation, damp-proofing, and cable installation are discussed, and the importance of good screeds, properly laid, is emphasized. The information is based on experience gathered from many sources all over the country since this method of heating was introduced, and is correlated with the work of the Building Research Station and the relevant British Standards and Codes of Practice of the British Standards Institution.

—and a folder for salesman or householder

An EDA folder, *Electric Floor Warming, Questions and Answers*, has also been produced, answering queries such as those on heat insulation of both floor and house, recommended floor finishes, the raising of dust, effect of carpets, and running costs, etc.

Copies of the booklet (EDA 1926) and of the folder (EDA 1934) can be obtained from electricity service centres or from EDA, 2 Savoy Hill, London, W.C.2.

One of the large drums of A.E.I. 3-core 132kV oil-filled cable being jacked into position for laying during cabling inside the Esso oil refinery at Fawley.

POWER for Oil Cracking

THE SOUTHERN DIVISION of the Central Electricity Generating Board has within its administrative area the huge Esso oil refinery at Fawley, sited on the west side of Southampton Water.

One year ago the Board awarded to Associated Electrical Industries a contract for oil-filled cable which was primarily intended to provide electric power reinforcement to this refinery, but would also serve the surrounding industrial estates.

However, other projects in this area are dwarfed by the Esso refinery. On a 1 000 acre site, with its £70 million worth of equipment, its stills and furnaces working twenty-four hours a day, marked by spotlights and the glow of burning gas at night, automobile spirit is produced from crude oil and a large number of by-products are obtained by the latest methods of petroleum chemical manufacture.

A visitor to the refinery has a strange feeling that only machinery is at work here, that the stills and retorts are its only sentinels, for in spite of the sounds of continuous

processing little human activity is to be seen. In fact, automation in the refinery means that over this large area only 250 men are needed at any time to operate the plant.

Future progress at Fawley is the reason for the provision of more electric power. The scope of the A.E.I. cable contract was for the supply, installation, and jointing of some 2 500yd of 132kV oil-filled cable and 50 000yd of 11kV and multicore auxiliary cables. The work, worth more than £95 000, is being carried out by the A.E.I. Construction (Cables and Lines) Division.

From Marchwood Generating Station, a 185yd run of three 132kV single-core oil-filled cables has been installed, terminating in sealing ends on reinforced concrete structures and connecting to overhead lines which run to Fawley North substation. This substation, and the Fawley South substation, are situated within the confines of the refinery some 1 500yd apart. The remaining 132kV cable-laying took place at these substations and between them, by the side of the access roads and over rough ground inside the refinery. Owing to numerous obstructions encountered below ground, this route proved very difficult to trench.

Corrosive Soil

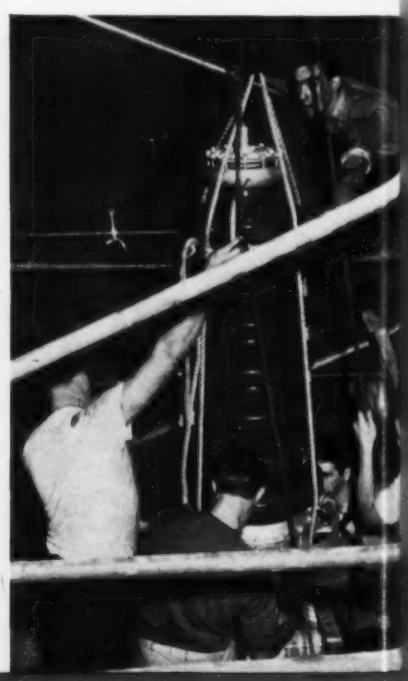
Low lying and partly waterlogged ground, subject to contamination by seepage of oil and chemicals from refinery processing, necessitated cable coverings affording complete protection against corrosion. As an additional safeguard A.E.I. were requested to install a system whereby tests of the serving could be applied after the installation was completed—instead of the more usual test after laying only, as specified in British Electricity Board Specification C4.

The 11kV cables (solid type 1·25sq.in. lead alloy sheathed and served cables) are part of the new Lynes Common substation installation, which is sited outside the refinery between the power station and Fawley North substation. The auxiliary cables—a 19-core 7/·029 cable and a 37-pair 1/·044in. telephone cable—are routed from Marchwood Generating Station first to Lynes Common, on to Fawley North, and then to Fawley South substations—a route distance of approximately 7½ miles. The first part of this route, some 5½ miles long, is through a marshy stretch of land which, liberally supplied with additional moisture by the "summer" weather of 1960, caused considerable difficulty to construction work by continually flooding the cable trenches.

Telephone Circuit Protection

The telephone circuits, being in proximity to adjacent power cables and overhead lines and liable to additional induced potentials from lightning storms in this area, have each core protected by the installation of the latest type of A.E.I. gas-filled two-electrode protectors at terminations in station cubicles. These protectors can handle 100 joule discharges in which the peak current is of the order of 3 500A.

The contract at Fawley also involved considerable jointing of 132kV oil-filled sealing ends at terminations in the substations and the installation of pressure tanks and ancillary equipment.



Jointing the 132kV oil-filled cables at Fawley

In the picture on the left, the jointer in the foreground is applying a wire binding preparatory to cutting the top chamfer of the stress cone, while the jointer in the background is cutting the top chamfer on another cable. The centre picture shows a 132kV sealing end being lifted over the completed cable termination before lowering it into position (*right*).

Reinforcing the Supply for Vauxhall Motors' Growing Demand

A production car emerges from the Vauxhall Motors' works to where A.E.I. engineers were laying cables under the main road.

NEARLY ONE THOUSAND vehicles a day roll out of the Vauxhall Motors' works at Luton. During cable-laying work for the Eastern Electricity Board's Chiltern Sub-Area by engineers of the A.E.I. Construction (Cables and Lines) Division, part of the route was under the centre of the main road outside the works and the traffic problem added to the difficulties of laying the cables along this section.

To meet the growing demand of the Vauxhall works for electricity E.E.B. engineers planned two 33kV feeders and their associated pilot cables between their Kimpton Road substation and the Vauxhall Motors substation. The contract for the supply, laying, and jointing of the cables was given to the A.E.I. Construction Division.

Over the short route length of some 1 000yd the two 0·3sq.in. 33kV cables and two pilot cables cross the main-line B.R. Midland Region tracks passing through Luton, under which they were accommodated on hangers in a brick-built culvert. Under private ground on the further side of the tracks they are drawn through four 6-in. steel pipes set in concrete below ground level and on this section the feeder cable sizes are increased to 0·4sq.in. The feeders comprised 700yd of 0·3sq.in. 33kV 3-core PLYSWS cable, 350yd of 0·4sq.in. cable of similar construction, and 990yd of 0·3sq.in. 33kV 3-core PLYSWS "HSL" type cable (cores individually lead-sheathed). The pilots were 7/·029in. 6-core plus 22 pair 1/·044in. polythene-insulated PVC.SWA.PVC cable.

Under the same contract 1 260yd of 0·75sq. in. 11kV single-core PLYS cables are being installed, serving as secondary connections between the 33kV to 6·6kV transformers and associated oil-circuit-breakers in the substation.

Construction Division's Smart New Oil Van

A new oil van for the Construction (Cables and Lines) Division took the road recently. Here it is, a specially adapted Bedford, smart in its new grey paint and yellow insignia, before going "on location" to an oil-filled cable installation.

Arrowed Poles take a bow

IF YOU KNOW the Royal Forest of Dean, between the rivers Wye and Severn, an area of woodland glades and scenic beauty, you have fortunate knowledge of a rambler's paradise. The area is a reminder that here in the densely populated southern parts of Britain we yet have countryside where it is possible to lose one's way.

The Forest is such a maze of tracks that its deeper precincts are relatively unused by the younger walkers, or those unsure of their map-reading skill. So the Ramblers' Association decided to mark out, with yellow painted arrows, one of the Forest's most beautiful walks —a fourteen-mile tramp between the youth hostels of St Briavels and Mitcheldean—to encourage more people to use the Forest.

And that was how the Midlands Electricity Board came to be asked whether they would mind some of their poles bearing a yellow arrow! Quoting from *Midlands Electricity*, the lively magazine of the M.E.B., this is what happened when the Ramblers' Association set about marking the walk:

> . . . for most of the way the arrows are painted on the trunks of large trees, gateposts, or other landmarks. At about a dozen points, however, the Association found itself in difficulty. There were no particularly prominent trees, no gateposts—but there were overhead poles supporting the M.E.B.'s 11kV distribution system. So they wrote asking permission to use the poles by marking them with the yellow arrows.
>
> "Although such eyesores really, the poles have come at the most useful places," said Mr Drake, Gloucester Secretary of the Ramblers' Association, in a grudging compliment.
>
> The Board were naturally glad to co-operate, and Mr R. P. G. Brain, Dean Forest district engineer, gave permission for the arrows to be painted.
>
> The new route, apart from providing wonderful scenery, also passes the Speech House, the hotel which is also the meeting place of the Verderers' Court, first appointed by King Canute in 1016.

Mr R. P. G. Brain, district engineer, points to one of the arrows painted on an M.E.B. pole as a guide to ramblers.

Book Reviews

Introduction to Modern Network Synthesis
By **M. E. Van Valkenburg**
Chapman and Hall
498 *pp.* *Price* 94*s.* 0*d.*

This is a textbook of network design intended for advanced students who possess a knowledge of network analysis and the Laplace transformation.

Of the sixteen chapters in the book, the first two cover some of the ground which should be familiar to students of network analysis. Following these are a study of Brune's positive real functions, procedures for the synthesis of LC, RC, RL, and RLC one terminal-pair networks, the relationship between network functions, approximation methods, and two terminal-pair synthesis. Chapters 14 and 15 cover resistively terminated and double terminated networks, and the final chapter is an examination of the image parameter method of synthesis.

The emphasis throughout the book is on communication network theory but, in so far as a knowledge of modern network theory is necessary to the electrical engineering graduate, the text will be found of essential interest to the serious student.

The author has followed the excellent procedure of illustrating the text wherever possible with explanatory diagrams, resulting in a truly valuable volume.

The Photoconductivity of Solids *By* **R. H. Bube**
Chapman and Hall
460 pp. *Price* 118*s.* 0*d.*

Photoconductivity, treating of changes in conductivity due to illumination, has, in this book, its first comprehensive volume on the photoconductivity of solids.

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